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(54) **Radiography apparatus including a photographic film memory**

(57) For recording images, a radiography apparatus 2, 10 includes a camera 24 for a small format film, for example, 35 mm film. In a film development device 26 and a film scanning device 28 with an analog-to-digital converter, the images selected from the film images thus recorded can be converted into digital images and stored 42. These images can be used to form hard-copy images 44 or television monitor images 59, they can also be used as identified digital images in, for example, an optical digital video disc 50.

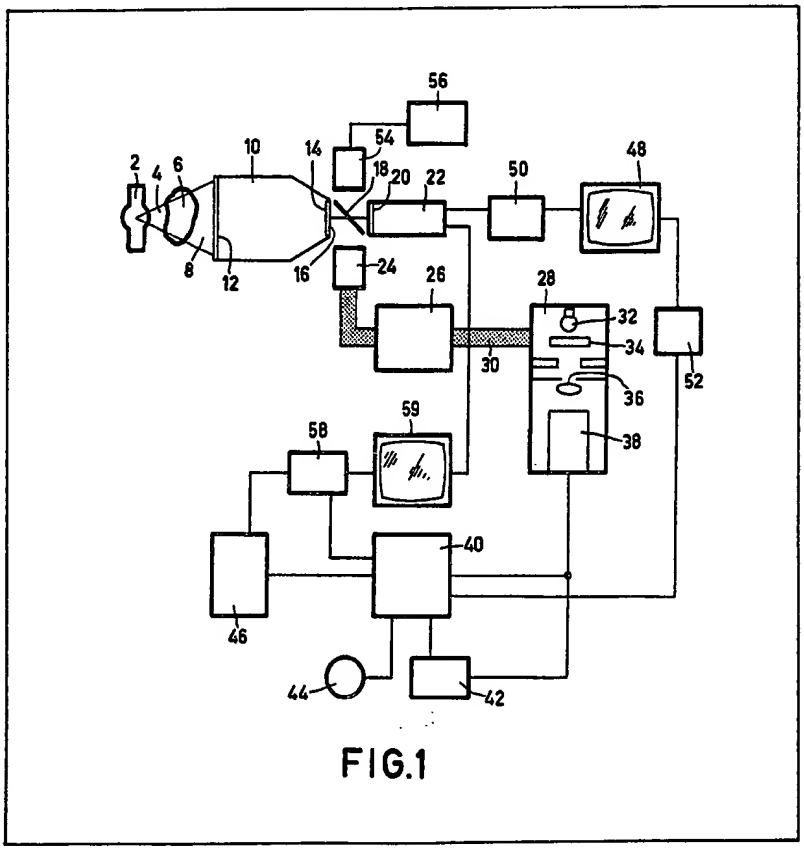

FIG.1

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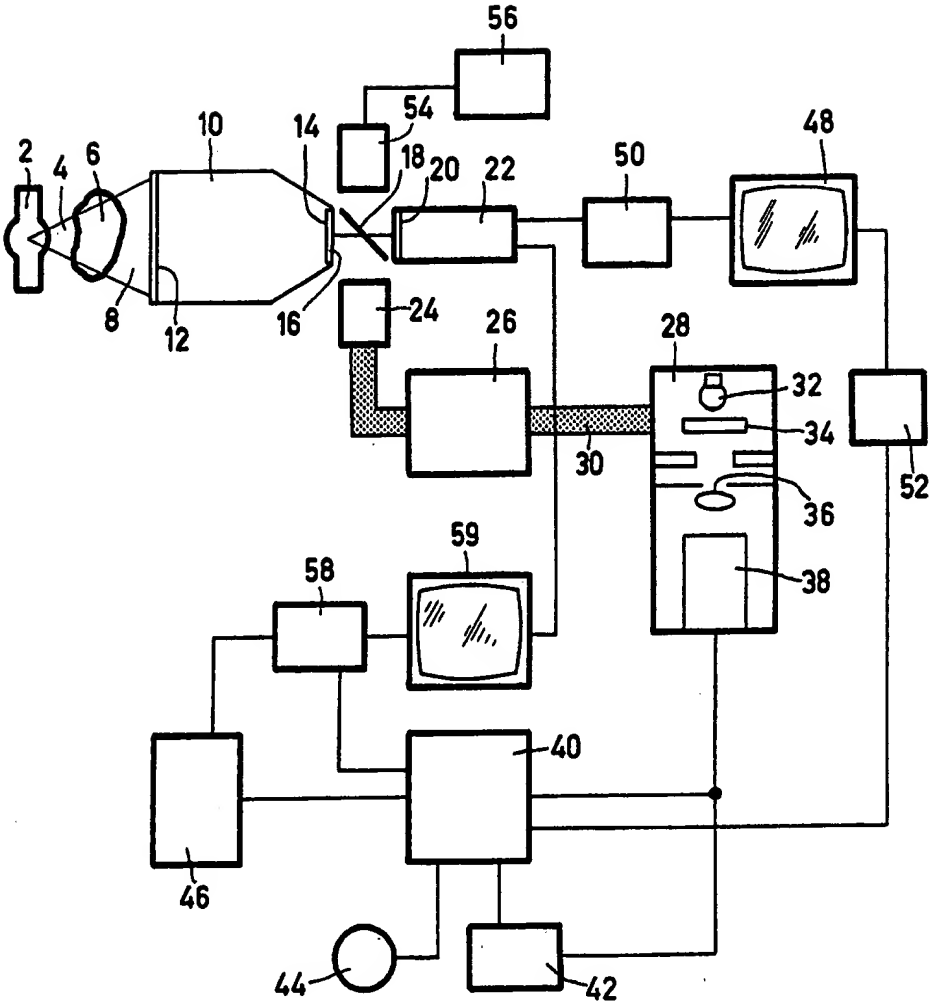
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FIG.1

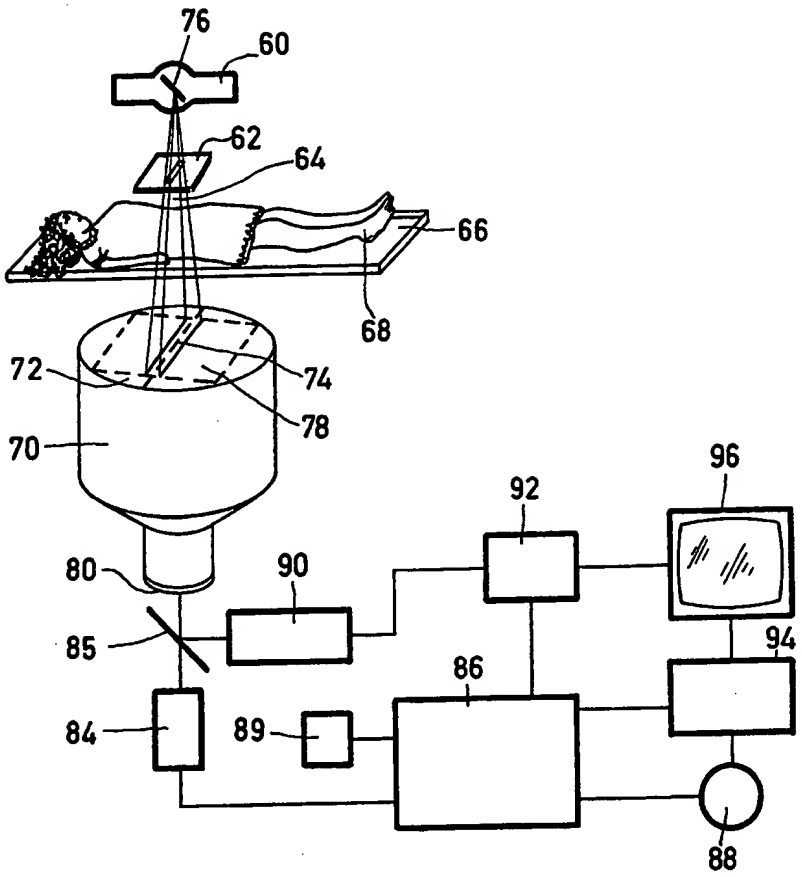

FIG.2

SPECIFICATION

Radiography apparatus including a photographic film memory

The invention relates to a radiography apparatus, comprising a radiographic-image-forming device and an image recording device including a radiation detecting device, and will be referred to herein as radiographyc apparatus of the kind referred to.

An apparatus of this kind in the form of an X-ray diagnostic apparatus is known from US 4,220,890. In an apparatus described therein images can be formed of an object which are recorded on a photographic film. These radiographs need to be of a large format, because the images must be recorded with high contrast for later diagnosis. Large format radiographs require a large amount of film material and the filing of the large format has some important drawbacks. For example, the selective retrieval for later evaluation is difficult and filing requires large amounts of storage space. US 3,700,329 describes a method which allows a reduced format to be used, notably for filing, as a result of the use of film material with two different contrast gradients. However, it is a drawback thereof that in order to satisfy the requirements imposed, the film in comparatively expensive.

The invention has for an object to provide improved radiography apparatus of the kind referred to in which the said drawbacks are reduced. According to the invention there is provided a radiography apparatus, comprising a radiographic-image-forming device and an image recording device including a radiation detector, characterized in that the image recording device includes a photographic film camera for recording images using a comparatively small film format, as herein defined, a film development device, a film scanning device for scanning the images thus recorded to provide corresponding electrical output signals, an analog-to-digital converter, and a recording device for recording digital signals generated by the analog-to-digital converter from the electrical output signals from the film scanning device.

In an apparatus in accordance with the invention, the two functions of the radiograph, that is to say the recording of an image for possible later image processing (buffer recording) and the reproduction of diagnostic information are separated. When the radiographs are used only as a buffer recording, they need not have the high image quality, such as a high gamma value, required for direct diagnosis. In known devices the functions of recording and image reproduction are always combined, so that it is often necessary to use a large film format and film material having a high gamma value.

In an apparatus in accordance with the invention, these functions are separated so that for the buffer recording function use can be made of a small format customary film material having a comparatively low sensitivity. For recording diagnostic images, for example, for direct diagnosis or for filing, the buffer recording is scanned after development, for example optically, and is displayed for example on a monitor, after digitizing, or is applied to a digital image recording device which is capable of reproducing the image, for example by means of a hard-copy device.

Advantages of the use of a reduced film format for the buffer recording over, for example, electronic buffer memories are: low cost, large dynamic range, high resolution and hence high information density, fast recording, simple processing and excellent long-term storage properties.

A preferred embodiment in accordance with the invention comprises an X-ray image intensifier tube to which a 35 mm photographic film photographic film camera is optically connected. If desired, a television camera forming part of video recording apparatus, may additionally be connected thereto.

A further preferred embodiment includes a device for combining digitized images so that image summing and image subtraction can be performed by making only a small addition to the equipment which is already provided for processing digitized images.

A further preferred embodiment includes a detector device with an array of detectors which can be individually read. This device may comprise an X-ray source with a collimator for forming a narrow, fan-shaped beam, the detector device forming a linear array of detector cells. This apparatus may further be constructed as, for example, an X-ray, emission or accoustic scanner or scanography apparatus or an apparatus in accordance with US 4,179,100. The latter preferably includes an X-ray image intensifier tube as the detector device.

A hard-copy device for the selective production of hard copy images to be filed or evaluated, can be connected to apparatus in accordance with the invention.

Some preferred embodiments in accordance with the invention will now be described by way of example, with reference to the accompanying drawings, of which:

Figure 1 diagrammatically shows radiography apparatus including an X-ray image intensifier/television chain, in accordance with the invention, and

Figure 2 diagrammatically shows an X-ray radiography apparatus in accordance with the invention which utilizes a fan-shaped beam.

The radiography apparatus shown in Figure 1 is an embodiment of the invention and comprises an X-ray tube 2 for forming an X-ray beam 4 whereby an object 6 can be irradiated. An image information carrying part 8 of the X-ray beam is detected in known manner by an X-ray image intensifier tube 10. The tube 10 is provided with an entrance screen 12 comprising a supported layer of a fluorescent material, for example, as described in US 3,825,763, on which there is provided a photocathode.

Using a surface area reduction of approximately 10 times, an electron image of the photocathode is formed on an exit screen 14 which comprises a layer of a fluorescent material. In this layer the electron image is converted into a light optical output image which can be read from the exit end 16 of the tube.

Using an optical system of which only a semi-transparent mirror 18 is shown, the output image can be projected onto an entrance window 20 of a

television camera tube 22 and onto a small format photographic film camera 24. The film camera 24 is, for example, a 35 mm camera. The apparatus furthermore comprises a film development device 26 and a film scanning device 28 which are interconnected *via* a film transporter 30. The film scanning device comprises a light source 32, a selectable masking mechanism 34 for adjustment to different film formats, for example, between 35 and 105 mm, a lens system 36 for pixel-wise projection onto a detector 38 for further pixel-wise processing in a computer 40. A magnetic storage device 42 and a device 44 for the optical recording of digital signals may be connected to the computer 40.

35 mm film images of the object 4 are recorded developed and scanned in the film scanner 28, followed by a conversion into digital image information. The image information can be stored, *via* the computer 40, in the magnetic memory 42 or in the optical/digital memory 44. Using a hard-copy device 46, an image of the image information can be provided at will in a suitable image format for examination. The apparatus may also include a television monitor 48 for the display of images directly from the television tube 22, or *via* a multi-track video disc memory 50, or from one of the digital memories, in this case *via* a digital-to-analog converter 52. The video disc memory 50 can also be used to test, immediatley after recording an image whether the image is error-free and whether the quality of the image with respect to exposure etc. is acceptable. These images per se need not have a quality sufficient for diagnosis, but can provide enough information for a decision to be made as to whether further recordings are necessary or whether the patient may leave the apparatus. It is to be noted that such a check would only relate to images obtained directly *via* the television apparatus. No information can be derived therefrom relating to the operation of the 35-mm camera. Therefore, it may be advantageous to use a reference standard, for example in the form of a sensitometric wedge in an appropriate manner for automatic process control in the film development device. However, the density is less critical for these images, because they only serve as buffer recordings and can to a certain extent be optimized in this respect after digitizing.

A hard-copy image can thus be made of a limited number of images selected from a long series of 35-mm film images, possibly a cine film. This can offer a substantial saving in respect of film material, even when the few hard-copy images are made in the large format on normal radiographs. For the indentification of radiographs, the image recording device may be provided with an information display device 54 which can be controlled by a control unit 56, the latter using, for example, a magnetic card on which patient data, image numbers, and even instructions and data relating to the camera and the film developer can be provided.

This information can be provided on the film, for example, in a space between two images or at the side of the respective images. In an apparatus of the described kind only a small technical extension is necessary for combining digital images, because digitized images are already present. To achieve this, the apparatus may be augmented by an image combining device 58. An image combining device of this kind is known from US 4,204,225 in which it is employed notably, for image summation and image subtraction. Each image stored in the memory of the computer can them be combined with any other image. Alternatively, a series of images can be summed and combined with other images. A second television monitor 59 may be included for the display of images thus formed.

For example, for effecting subtraction between a current image and a previously formed image, the current image may be supplied to the device 58 directly from the analog-to-digital converter. Combined images, such as subtraction images, can also be printed as hard-copy images.

The further embodiment shown in Figure 2 comprises an X-ray source 60 with a slit-shaped diaphragm 62 for forming a fan-shaped X-ray beam 64 by means of which a patient 68 arranged on a table 66 can be irradiated. Beneath the table there is arranged an X-ray image intensifier tube 70 having an entrance screen 72 which intercepts the X-ray beam 64 after having passed through the patient to form a strip image 74. The X-ray image intensifier tube is preferably a 14 inch tube as described in US 4,213,055. The X-ray beam can be moved in a direction transversely with respect to the plane of the fan by a translation or by a rotation, for example, by a pivoting movement of the X-ray source together with the diaphragm about the focal spot of the X-ray tube 76. In this way a part of the patient which correspods to a field 78 can be scanned in a line by line manner.

The dimension of the region to be examined during each scanning motion is thus determined by the size of the entrance window of the X-ray intensifier tube and by the position of the tube with respect to the source and the patient; *inter alia* in view of this aspect, the intensifier tube should be mounted as close to the table as possible. For an account of various scanning methods and further signal processing operations by means of such an apparatus, reference is made to US 4,179,100 and PHN 9820. A 35-mm film camers 84 is optically connected to the output end 80 of the tube 70 *via* an optical distribution system 82 for recording each of the slit images. When the film transport speed is adapted to the speed of motion of the slit 74 across the entrance screen, the slits can be adjacently photographed on the film, even when the X-ray image intensifier tube or the line detector also moves. An image of the total field can also be recorded in one sweep in the case of synchronized film and sweep movement. After development, scanning etc., hard copies can again be made thereof *via* the computer.

The camera 84 is connected, if desired, *via* intermediate film storage, to a film developer device with a film scanner, an analog-to-digital converter, etc., in a manner similar to the embodiment described with reference to Figure 1; in this case these devices are shown as a single film processing unit 86 to which a recording device 88 for digital signals and a hard-copy unit 89 can be electrically connected as before.

The X-ray image intensifier tube is also optically connected to a television camera tube 90 which forms part of an X-ray image intensifier/television chain 92, for example, as described in GB Patent Specification No. 1,278,944. Using a signal processing device 94, on-line signal processing can be performed and images exhibiting only small differences in contrast can be formed by means of the computer using known window techniques, for display on a monitor 96.

Further applications can be found, for example, in video fluorography utilizing a 35-mm camera for the formation of small images, a film processor, a film scanner, an analog-to-digital memory and a hard-copy device. A substantial saving of film can again be achieved by selecting the images to be used for further evaluation or storage on the basis of the 35-mm images.

A system in accordance with the invention can comprise an analog-to-digital converter and a computer, which in practice can be formed by a microprocessor unit to which a recording for the recording of digital signals is connected.

A device in accordance with the invention can be simply connected to a filing system which comprises, for example, an apparatus for the optical recording of digital signals. This is because the radiographs selected for filing can be recorded on-line on an optical disc and cqn be provided with patient indentification and information for retrieval at a later stage.

The connection between an X-ray apparatus and the filing system is also is provided by the use of 35-mm film as the buffer memory. A greater freedom is thus also provided for coupling given X-ray equipment to a filing system. In a manner similar to the conversion of images formed by the present X-ray apparatus into optically recorded digital image information, existing large format film images, for example, in an already existing file, can be converted into optically recorded digital image information. It will be apparent that this is also applicable to images produced by means of other radiation equipment, for example equipment used for nuclear medical examinations.

The 35-mm photographic film camera can also be used in ciné film sequence, The ciné images are recorded by means of a television camera on, for example, a 500-track video disc. After a recording cycle, the images are displayed and the physician can specify and mark each image of which he requires a hard-copy or which he wishes to file. This information is applied to the computer. The ciné film can also be developed, after which the film scanner or the analog-to-digital converter is arranged to process only the identified images.

Where the described embodiments utilize a 55-mm camera, use can alternatively be made of other camera formats, such as a 70-105 mm camera. The resultant images will be approved as the film format is made larger, but the saving will then be less. An optimum choice can be made for each application.

CLAIMS

1. A radiography apparatus, comprising a radiographic image-forming device and an image recording device including a radiation detector, characterized in that the image recording device includes a photographic film camera for recording images using a comparatively small film format, as herein defined, a film development device, a film scanning device for scanning the images thus recorded to provide corresponding electrical output signals, an analog-to-digital converter, and a recording device for recording digital signals generated by the analog-to-digital converter from the electrical output signals from the film scanning device.

2. A radiography apparatus as claimed in Claim 1, characterized in that the image recording device comprises an X-ray image intensifier tube and a small format pnotographic film camera as herein defined, which is connected optically to an exit window thereof.

3. A radiography apparatus as claimed in Claim 2, characterized in that in addition to the small format film camera, a television camera with a video recording device is optically connected to the exit window of the X-ray intensifier tube.

4. A radiography apparatus as claimed in any one of the precéding Claims, characterized in that the apparatus further includes a digital image processing device.

5. A radiography apparatus as claimed in Claim 4, characterized in that the radiographic-image-forming device is a multi source encoding tomography system, the image processing device being adapted for exact decoding superposition of images to be used for making combined images.

6. A radiography apparatus as claimed in any of the preceding Claims, characterized in that it comprises an image selection device and a hard-copy device for selective production of hard copies.

7. A radiography apparatus as claimed in Claim 1, characterized in that the image recording device further includes a set of X-ray detectors which can be separately read.

8. A radiography apparatus as claimed in Claim 7, characterized in that the radiographic-image-forming device comprises a computerized X-ray tomography apparatus in which an X-ray source is provided with a collimator for forming a fan-shaped X-ray beam.

9. A radiography apparatus as claimed Claim 7 or 8, characterized in that the image recording device includes a television camera tube which is arranged to provide high resolution video signals of improved dynamic range.

10. A radiography apparatus as claimed in Claim 1, characterized in that the film scanning device comprises a basic scanning device and an optical system which can be adjusted to accommodate different film formats.

11. A radiography apparatus of the kind referred to, substantially as herein described with reference to the accompanying drawings.

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